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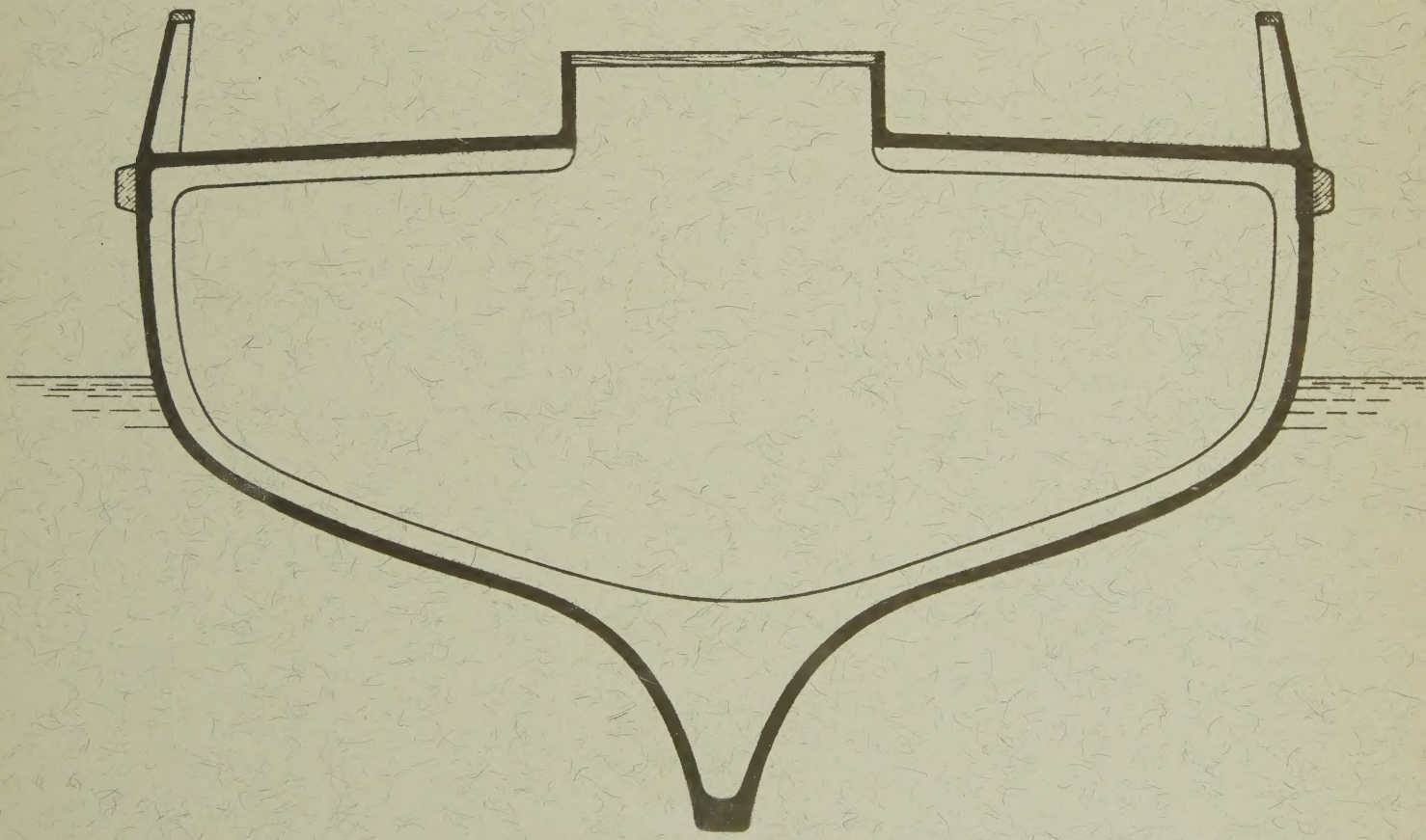
Report of the

SEMINAR ON THE DESIGN AND CONSTRUCTION OF FERRO-CEMENT FISHING VESSELS

Wellington, New Zealand, 9-13 October 1972



FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, 1973

REPORT OF THE SEMINAR ON THE DESIGN AND CONSTRUCTION OF FERRO-CEMENT FISHING VESSELS

Wellington, New Zealand, 9-13 October 1972

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, January 1973

PREPARATION OF THIS REPORT

Report of the Seminar, Summary of Proceedings and the opening addresses.

Distribution:

FAO, Department of Fisheries
FAO, Regional Fisheries Officers
Invited Member Countries
UNIDO
IMCO
Participants in Seminar

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Fishery education and training. Reports of international organizations - seminar on design and construction of ferro-cement fishing vessels. Sessions and discussions. Sessions papers. Lists of participants and officers.

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BACKGROUND

The purpose of the Seminar was to collect as much data as possible on existing ferro-cement boats in terms of construction methods and costs, scantlings and service experience and to discuss the properties of ferro-cement as a boatbuilding material from a theoretical point of view and by making comparisons with other boatbuilding materials such as wood, steel and FRP.

Mortar reinforced with steel mesh is known to have been used as a boatbuilding material over 100 years ago. The present-day technique of ferro-cement construction must, however, be attributed to Pier Luigi Nervi of Italy, who developed the material in 1939 and first used it for marine construction during the second world war.

Twenty years after Nervi's experiments, ferro-cement boatbuilding was developed by British and New Zealand builders. At the present time, the areas of the world where ferro-cement workboats have mostly been built and operated are South-East Asia, Australasia, the Pacific coast of North America, Europe and the Caribbean.

For some time FAO has been interested in the use of ferro-cement for the construction of fishing vessels in developing areas and, over the last 3 years, has constructed prototype vessels in Africa, Asia and the South Pacific.

Several classification societies and governmental bodies are preparing guidelines for the construction of ferro-cement vessels. These are based almost entirely on past service experience but they will no doubt be modified as the engineering properties of the material, as applied to boatbuilding, become established.

While FAO is mainly interested in fishing vessels and other workboats, the lessons of experience with yachts and pleasure craft are also useful for the improvement of the design and construction of ferro-cement boats.

As in many other fields of engineering, with ferro-cement at present there is a gap between the laboratory and the boatyard. One of the most difficult questions to answer, for example, is "how strong is strong enough?".

It was in response to this background and needs that this seminar was organized.

SPONSOR

The Government of New Zealand offered to act as host for the seminar and to provide all necessary facilities and local staff support at the James Cook Hotel, Wellington.

ORGANIZATION

Invitations were sent from the FAO Director-General's office to all Member Governments of the Indo-Pacific Fisheries Council (IPFC) and to selected Member Governments in other parts of the world with a special interest in ferro-cement technology and its application for fishing boat building.

In addition to a number of internationally renowned authorities on the subject, fisheries institutions, private industry, research institutions, international organizations and classification societies were invited to send participants.

Selected authorities were invited to present papers on the main subjects covered by the agenda. Altogether 25 papers were accepted and distributed prior to the seminar, while about 10 major written contributions to the discussion were received and distributed during the seminar.

All papers were written in English and, in the absence of government delegations from non-English speaking countries, the seminar proceedings were conducted in English only.

TIMETABLE

8 October, Sunday	
14.00-17.00	Registration - James Cook Hotel, The Terrace, Wellington
9 October, Monday	
08.30-09.30	Registration - James Cook Hotel
10.00	Opening Ceremony - Legislative Council Chamber, Parliament Buildings
11.15-12.15	Session I - Material Properties
14.00-17.30	Continuation of Session I
Evening	Films and Slides Show
10 October, Tuesday	
09.00-12.30	Continuation of Session I
14.00-17.30	Sesssion II - Scantlings
11 October, Wednesday	
09.00-12.30	Session III - Construction methods, cost of construction and comparison with other materials
14.30-17.00	Continuation of Session III
Evening	Reception given by the Government of New Zealand
12 October, Thursday	
08.30-12.00	Session IV - Service experience
14.00-16.00	Continuation of Session IV
16.00-16.30	Closing Session
	POST-SEMINAR TOUR OF AUCKLAND BOATYARDS
19.05	Flight departure for Auckland
20.05	Arrival Auckland
13 October, Friday	
08.30-15.30	Tour of Auckland Boatyards

PARTICIPATION

The seminar was attended by 82 participants from 17 countries and one international organization (UNIDO). The complete list of participants is given in Appendix IV.

OFFICERS

Mr. B.T. Cunningham, Director of Fisheries, New Zealand, was appointed Chairman of the meeting. The following participants served as session rapporteurs:

Dr. R.P. Pama (Thailand)
Dr. H.M. Moar (New Zealand)
Dr. J.C. Scrivener (New Zealand)
Prof. M.A. Mowbray (New Zealand)

A full list of officers is given in Appendix V.

ACKNOWLEDGEMENTS

The Organization extends its grateful thanks to the Government of New Zealand for hosting the seminar.

The Ministry of Foreign Affairs, through its Conference Liaison Division, the Ministry of Transport, through its Marine Department, and the Ministry of Agriculture and Fisheries, through its Fisheries Division, were most generous in assisting the FAO Secretariat with personnel services and facilities and in making available key staff to participate in the seminar.

The hospitality of the Government and the reception given by the Hon. Minister of Transport were most appreciated by the participants.

OPENING CEREMONY

The importance attached to the seminar by the Government was underlined by the arrangements made for the opening ceremony held at the Legislative Council Chambers in Parliament House.

The Seminar was formally opened by the Hon. D.J. Carter, Minister of Agriculture and Fisheries (Appendix I), in the absence of the Hon. J.B. Gordon, Minister of Transport, whose plane was diverted from Wellington due to bad weather.

Mr. P. Gurtner spoke on behalf of FAO (Appendix II).

Mr. B.T. Cunningham, Director of Fisheries, New Zealand, addressed the Minister and the participants after his nomination as chairman (Appendix III).

PROCEEDINGS

Session I - Material Properties

(Monday, 9 October 1972/Tuesday (a.m.) 10 October 1972)

Mr. B.T. Cunningham (New Zealand) in the chair
Dr. R.P. Pama (Thailand) acted as rapporteur

Session Papers

I/1 "Investigation into the intensity and distribution of cracking in ferro-cement panels subject to flexure" by T.E. Buchner

I/2 "Panels of ferro-cement, glassfibre reinforced polyester and plywood subjected to dynamic point loads" by H.P. Pedersen

I/3 "Concrete technology in the quality control of ferro-cement vessels" by T.G. Kowalski

I/4 "Strength and cracking of ferro-cement" by S.P. Shah and M.G. Srinivasan

I/5 "Mechanical properties of ferro-cement" by Seng-Lip Lee, Murlidhar Raisinghani, Ricardo P. Pama

I/6 "Basis for a definition of ferro-cement" by D.J. Howard

I/7 "Practical ferro-cement design - Reinforced and post tensioned" by Peter E. Ellen

I/8 "A definition of ferro-cement" by G.W. Bigg

I/9 "Ferro-cement - The design of its properties to meet the requirements of marine usage" by H.M. Moar

Papers also relevant: III/3, III/4, IV/1

Rapporteur's introduction of papers

From the engineering point of view, material properties relate to the behaviour of the material at various stages of loading. This includes the various constants and strength of the material for different loading conditions.

Several authors attempted to analyse ferro-cement as a composite material with cement mortar as the matrix and the wire mesh as the fibres. Shah and Srinivasan, Lee, Raisinghani and Pama, and Bigg all advocated the use of the law of mixture of composite material in analysing the behaviour of ferro-cement at various stages of loading.

In these papers, the material, with non-linear load deflection curve, is idealized as a tri-linear material. In this idealization, the non-linear load deflection curve is replaced by three straight lines for convenience in the analysis. In the uncracked range, the strength and modulus of elasticity of the composite are determined from the laws of mixture of composite material which have been shown to be a function of the basic mechanical properties of the constituent materials and their respective volume fractions. The same is done in the cracked range, except that the contribution of the mortar is neglected as it is assumed to have cracked. It is in the determination of the ultimate strength of ferro-cement in bending (crack widening range or yield range) that these authors have differed. Shah and Srinivasan quote a formula for the ultimate bending moment of the material (due to Tancrete and Hayes) as:

$$M_{ult} = \frac{(\text{Tensile strength of mesh})\ \text{Moment of inertia of wire mesh}}{\frac{1}{2}\ \text{depth}}$$

This formula is derived from the assumption of a classical homogeneous elastic beam. How accurate this method is in predicting the ultimate bending moment of ferro-cement is questionable. The concrete and the steel in the compression side is considered as the compression flange of the equivalent girder and the wire mesh in the tension side as the tension steel.

The third approach, advocated by Lee, Raisinghani and Pama, is based purely on the equilibrium and stress-strain law of the material, as outlined in their paper. It is derived on the basis that the concrete carries the compressive stresses and the steel in the tension side carries all the tensile stresses and these two create forces which are in equilibrium. The couple formed is termed the ultimate moment of resistance of the section.

As far as the behaviour in axial tension, axial compression, flexure, shear and tension is concerned, the composite material approach was considered adequate. However, in service a vessel acts as a shell structure and the state of stress of an element is far

more complex. It is obvious then that one should also be concerned about the Poisson's ratio of ferro-cement and it appears that this particular mechanical property is not sufficiently considered.

The other property of ferro-cement which seems not adequately covered in the papers is the impact strength. Pedersen describes an experimental investigation on the impact strength of ferro-cement compared with fibreglass-reinforced polyester and plywood. Curves are given comparing panels of these different materials on the basis of cost, strength and weight.

The intensity and distribution of cracking in ferro-cement panels in bending is described by Buchner in his paper. He concludes that the most effective control of cracking in ferro-cement is obtained where the member develops a multitude of fine cracks spread uniformly over the surface rather than a limited number of large cracks at irregular spacing and of an intensity such as would expose the reinforcement to possible corrosion under working conditions.

Kowalski and Walkus deal with concrete technology in the quality control of ferro-cement vessels. They question the validity of using a standard control test specimen as for conventional reinforced concrete, since ferro-cement is a very thin material. Consequently, they suggest that smaller and different standard specimens should be used also for evaluating the properties of the mortar and ferro-cement.

Moar reviews the design of the properties of ferro-cement from the point of view of the manufacturer, designer and the user. He concludes that, although knowledge about the properties of the material is increasing, a lot of gaps remain to be filled.

Ellen presents formulae for determining the ultimate strength of ferro-cement by treating it as a reinforced concrete member. The formulae are derived from equilibrium consideration and the author extended his method of analysis to cover post-tensioned ferro-cement sections. It is claimed that, at working load, the post-tensioned section has greater strength and the weight is reduced by some 40% compared with an equivalent section which is conventionally reinforced.

It appears clearly that there is no standard set of terms or terminology used in ferro-cement technology. There is no established and acceptable definition of ferro-cement on which all design data, manufacturing methods and techniques and material evaluations may be based.

Howard and Bigg maintain that it is not adequate to define ferro-cement in terms of the mortar and steel only but that the other constituent materials which combine to form the mortar and the physical and chemical properties of the steel must be included.

Standard terms should be adopted and a code on the design, analysis and construction of ferro-cement structures may need to be developed.

Rapporteur's summary of discussions

It would appear that the mechanical properties of ferro-cement under static loading could be predicted quite accurately from the laws of mixture of composite material. The strength and modulus of elasticity of ferro-cement have been shown to be a function of the basic properties of the constituent materials, mortar and wire mesh and their respective volume fractions.

Impact resistance is one important mechanical property of ferro-cement on which little is known. The criterion chosen to define the impact resistance varies from author to author. It was suggested that the leakage rate of damaged material should perhaps be used as the criterion.

On the problem of cracking, it would appear that the important parameter involved in crack propagation is the specific surface of the material. It was also apparent from tests by Buchner that the most important factor controlling the intensity of cracking is the outermost layer of wire mesh.

The subject of definition of ferro-cement, or rather the lack of it, has been discussed in great length and an ad hoc committee was formed with the task of preparing a suitable definition of ferro-cement.

Development of ferro-cement as a combination material for marine applications is still in its early stages and cooperation and collaboration between research workers, engineers, chemists, designers, builders and users is required to arrive at satisfactory basic standards. It is heartening to note that a panel of the National Academy of Science of the U.S.A. has been formed to study the possibilities of application of ferro-cement as a low-cost construction material in developing countries.

Draft Definition of Ferro-Cement

(elaborated by an ad hoc committee composed of selected seminar participants)

Introduction

With the many configurations of steel reinforcement and mortar possible in a ferro-cement structure, it is difficult to define properly the material to suit the classifier, researcher, builder and user. To define the material too quantitatively is restrictive. On the other hand, to define the material too qualitatively is uninformative. Accordingly, the ad hoc committee decided that an essentially qualitative definition is appropriate at this time with minimum values assigned to basic parameters.

Ferro-cement

Ferro-cement is a composite material which consists of a matrix from hydraulic cement mortar with layers of continuous steel mesh reinforcement distributed through the matrix. The basic parameters which characterize ferro-cement are: the specific surface area of reinforcement, the volume fraction of reinforcement, the surface cover of mortar over the reinforcement and the relatively high quality of the mortar.

Mortar: Mortar shall mean a mixture of hydraulic cement, sand and water, with or without appropriate admixtures. The components are to be proportioned and of a quality consistent with standard practice for the production of a high quality mortar and the sand is to be of a uniform grading with the maximum particle size consistent with the placement of the mortar throughout the steel armature.

Steel Mesh Reinforcement: Steel mesh reinforcement shall mean a mesh that is woven, welded, or otherwise fabricated so that the maximum clear spacing between any parallel adjacent elements shall not exceed $\frac{3}{4}$ of an inch.

Specific surface area: Specific surface area shall mean the surface area of the mesh reinforcement divided by the volume of the reinforcement. It is to be noted that, if a skeletal steel framework is sandwiched between ferro-cement layers, as is common practice, the skeletal steel is not to be included in the determination of specific surface area. The minimum specific surface area shall be 3 in^2/in^3 (1.2 cm^2/cm^3).

Volume fraction: Volume fraction of the wire mesh shall mean the volume of wire mesh reinforcement oriented in a specified direction, expressed per unit volume of composite. The volume fraction of the mesh in any direction shall not be less than 1½%.

Volume fraction of the skeletal steel shall mean the volume of skeletal steel reinforcement oriented in a specified direction, expressed per unit volume of composite.

Armature: The armature shall mean the steel framework of the structure, complete with steel mesh reinforcement.

Skeletal steel: This shall mean any steel rod or pipe reinforcement located within the ferro-cement. Such additional reinforcement is frequently added for assembly purposes or for added ultimate strength. However, it is emphasized that that portion of the total thickness of material occupied by the skeletal steel framework is not properly classified as ferro-cement. The definitions presented herein apply only to that portion of the structure reinforced with the multitude of layers of mesh reinforcement as defined above.

Surface cover: Surface cover refers to the thickness of the matrix over the outermost layer of mesh. This thickness should not generally exceed 0.125 inches.

Session II - Scantlings

(Tuesday (p.m.), 10 October 1972)

Mr. B.T. Cunningham (New Zealand) in the chair
Dr. J.C. Scrivener (New Zealand) acted as rapporteur

Session Papers

II/1 "Ferro-cement boat hulls analysed by finite element method" by J.C. Scrivener and A.J. Carr

II/2 "Estimation of design loads" by G.L. Bowen

Papers also relevant: I/9, III/2, III/8, IV/1, IV/3

Rapporteur's introduction of papers

The two papers on scantlings are the theoretical or analytical side of the area. They discuss the hydrodynamic loading and possible full-scale testing (Bowen) and the analysis of hulls of given shape subjected to code loadings (Scrivener and Carr). It is significant that only two papers have been offered but perhaps this is a reflection of the complexity of the problem as it applies to small vessels.

Bowen reviews the complex question of the actual hydrodynamic loads and their calculation. He raises the query that perhaps these loads are not those to produce the greatest stresses in the scantlings and points out that the analysis of loads on large vessels is reasonably accurate and well documented but questions the applicability of these analyses to small vessels such as ferro-cement fishing boats.

Scrivener and Carr avoid the question of actual loading and apply a code load which is an estimate of the loading applied when a vessel is caught by a beam wave from each side. This may or may not be the most severe loading, or even a realistic loading for the scantlings, but it is a simple loading which at least allows an analysis to be performed. Some typical fishing boat hulls were analysed, using code hull thicknesses, with assumptions made on hull support and boundary conditions in order to be able to conduct an analysis. The ferro-cement strength was estimated from published results in order to reach conclusions with respect to transverse strength. Some brave guesses and assumptions had to be made in order to produce any answer at all.

Rapporteur's summary of discussions

The question as to whether hydrodynamic loads necessarily produce the most severe stressing of the scantlings is excellent and must be answered at some time. The effects of other loads must be considered, e.g., loads imposed by fishing gear, impact loads due to running aground, or loads due to brushing against wharves, piles or other vessels. It is queried whether sea loads or work loads are the deciding factor in causing damage.

What is needed is a qualified load or set of loads for use in design, termed a code load. Such a code load should be an envelope of loads or, more correctly, an envelope of stresses or responses, as one loading form may cause maximum stress in one part of the hull while maximum stresses in another part of the scantlings may be caused by a different loading condition. Inevitably, the probability of occurrence must be considered: "What is the probability of the maximum wave loading (largest in 20 years, say) striking the most vulnerable fishing vessel at the most critical angle?".

The code loading must also take into account workmanship and its variability. The final code loading may bear only the scantiest resemblance to actual loadings. The suitability of the code load lies in performance of vessels designed within its rules - there must be a large feedback to the code writers from those involved in service performance. It is interesting that the assumed code load and the various assumptions on ferro-cement strength, factors of safety, hull shape and thickness made by Scrivener and Carr result in an answer which agrees with the estimations of the practical men whose approach to the problem was from an entirely different angle. Perhaps from this one may infer that the code loading used is justified for vessels of this size.

Some interesting guidelines have resulted:

- the transverse bending moment is the only critical stress
- the most severe transverse bending moment depends most on hull length and little on hull shape
- where a local high of transverse BM occurs, a considerable thickening of the hull is necessary in order to ensure that severe cracking will not occur
- the most severe transverse BM's occur in the flat sections of the hull; this confirms the Sutherland advise to avoid concave areas.

The scantlings notes and guidelines circulated should prove useful although many differing viewpoints were aired. There appears to be a need for regulations but they must at this stage be as simple as possible. Restrictive rules tend to slow down development.

Many further problems will have to be investigated. The most critical is to decide what information is desired. Full-scale testing is an exceedingly costly operation, not only in the testing but also in the interpretation of the results. It is insufficient to recommend strain gauging the hull. Due to the large area involved, this is impossibly expensive and the quantity of results would be an immense task to process. Without exceedingly well controlled testing procedures one would be unsure of the effect of the many parameters of the problem. At best, one might instrument small portions of a hull (perhaps of existing hulls) - which ones would depend on what information was desired.

Further analyses and testing are required with the final hope that simple design rules may be produced.

Session III - Construction methods, cost of construction and comparison with other materials

(Wednesday, 11 October 1972)

Mr. B.T. Cunningham (new Zealand) in the chair
Dr. H.M. Moar (New Zealand) acted as rapporteur

Session Papers

III/1 "Construction, maintenance and repair of a 26-m ferro-cement stern trawler" by P.A. Leonard

III/2 "Ferro-cement vessels on the Pacific coast of North America" by Peter Noble and William Cleaver

III/3 "Construction of a 32-m ferro-cement barge and selected applications of ferro-cement in Thailand" by D. Nontanakorn

III/4 "Commercial production methods in New Zealand" by W.M. Sutherland

III/5 "A case study: Use of a cavity mold for constructing 15-metre ferro-cement fishing boats" by R.W. Behnke and E.C. Doleman

III/6 "The use of kitsets for amateur construction" by Graham Carkeek

III/7 "Explosive moulding of ferro-cement armatures" by J.C. Black and Robert C. Pickett

III/8 "Ferro-cement fishing vessels designed by FAO" by J.F. Fyson, Ø. Gulbrandsen, A.F. Haug and R. Lefebvre

III/9 "Weight and cost estimate for small fishing vessels" by Ø. Gulbrandsen

III/10 "A protective coating system for ferro-cement boats" by A.R. Pavey

III/11 "Cost of construction of ferro-cement boats in India" by M.A.K. Tayab

Papers also relevant: IV/1

Rapporteur's introduction of papers

The paper by Leonard of Hong Kong describes design problems and construction experience during the building of a 90' fishing boat, probably the largest so far built in ferro-cement. An interesting feature is the use of steel bulkheads welded to the reinforcement; it will be valuable to find out how a ferro-cement hull with a stiff bulkhead welded to the reinforcing will stand up and whether problems will occur with electrolysis. The hull thickness of this large boat is only about 1¼ in, which seems rather light and may be the reason for some of the damage the boat sustained during a typhoon.

The paper by Noble and Cleaver mentions refrigerated fish carrier barges. This is a very interesting development which may appeal to countries having limited capital availabl for investment in fisheries. Leaving catcher boats on the fishing grounds, rotating their crews and collecting the fish from the boats by using barges of this type would assist in making maximum use of the available equipment. Nontanakorn's paper discusses flat-sided barges built in Thailand for river work. Apparently these have been very successful and, in the light of discussion during previous sessions on the essential requirement of curved surfaces, it would be important to hear whether the flat-sided barges have given any problems or whether they have been perfectly successful. Sutherland's paper describes a

number of construction techniques, most prominently the sandwich construction method, consisting of a steel jig made up of web frames, rather like the pipe frame method. Longitudinal battens of timber are attached to this jig and layers of mesh are stapled to the battens on the outside. The outside layers of mesh are then plastered. After the mortar has cured, the jig is removed, the mesh stapled to the interior and then the inside is plastered. The timber is left inside the mortar. The method saves a lot of labour and is useful for low production runs.

Behnke and Doleman elaborate on the female mould technique. This is a very interesting method but one wonders if it would not have been easier to make a male plug first of ferro-cement and fair that, rather than to fair the interior surface of a female mould. Carkeek discusses the merits of pipe frames, timber frames and, in particular, truss frames. It appears that his company is very successful in making up truss frames but amateurs have had a lot of trouble with welding stresses and fairing. Gulbrandsen's paper on costs and weights would take a long time to absorb and discuss completely. Two well-made comments of his are: first, only hulls should be made in ferro-cement and not decks and cabins and appendages; there seems to be general agreement on this point, substantiated by a lot of service experience. Moar's own boatyard is only making the bare hull of ferro-cement. The second point he makes is that the cost savings made by using ferro-cement are not startling. By the time all equipment is installed and the boat finished they can turn out to be very small; American and Canadian experience may even indicate that a ferro-cement boat could be more expensive in first cost because of labour costs. Ferro-cement boats cannot easily be justified on cost alone and consideration needs to be given to other, more decisive, advantages of the material. Moar is convinced that there are many other advantages - some are listed in several of the papers - and he thought that these could be stressed. If low initial cost is to be of paramount importance, prospective boat owners would be better advised to consider other methods of saving money, such as reducing or simplifying equipment.

Pavey, discussing painting of boats, maintains that paint is necessary to cover the various areas of bare steel left after a boat is plastered. This appears to be a strong condemnation of bad amateur practices; a well-made boat, properly plastered, should not need painting.

Finally, Tayab recounts his successful experience in building a fishing vessel, using a pipe frame; he also reports the boat's success in practice. This is encouraging news from India where someone has started from scratch without apparent outside help and has successfully made and operated a fishing boat of ferro-cement.

The discussion should touch primarily on the following points, apart from considering the multitude of different construction methods identified and described in the papers:

- The lack of technical data and information as an inhibiting factor, delaying commercial acceptance of ferro-cement.

- The use of mixers. One paper claims that drum mixers are perfectly acceptable while other experience has been that these produce very poorly mixed mortar patches that could produce weak spots in the hull.

- Curing. Various curing techniques are suggested, including chemical, steam, water and salt-water curing.

- The advantages of ferro-cement.

- The extent to which ferro-cement should be used for vessel parts other than the hull.

Rapporteur's summary of discussions

Somebody enquired as to how big one could go with ferro-cement boats. If Behnke will allow us to put some reinforced concrete inside and if we can use a bit of pre-stressing, we should get ferro-cement boats built to a size comparable to the largest tankers we see today. It is interesting to note that there is now a ferro-cement submarine container being designed to transport liquefied natural gas. Ferro-cement boats are going to get bigger and bigger and there is no reason why the material should not equal steel in size and capacity. The tendency will be for application of pre-stressed concrete in combination with ferro-cement and the vessels will probably be submarines because of the natural advantages the material presents in this field. No doubt we are just at the beginning of ferro-cement development.

There was evidence of a divergence of opinion on many points, with Behnke disagreeing with Sutherland on moulding costs and suggesting that developing countries should beware of salesmen from ferro-cement companies and amateur ferro-cement enthusiasts. Hunt disagreed with the use of hydrochloric acid on boats and it was generally agreed that there was a lot to be done on working out a suitable painting system for ferro-cement. There was disagreement on how frames and bulkheads should be placed; this could be done by precasting, casting with the hull, casting after the hull was completed using starter bars, or by bonding timber or steel frames or bulkheads into place, using fibreglass or epoxy compounds. Disagreement was registered over mortar mixing, plastering and fairing techniques. The most favoured method is to mix the mortar in a paddle mixer, apply it in a two-stage method, using vibrating orbital trowels for the second stage at least. An excellent suggestion was the use of a serrated edged trowel in order to achieve a uniform cover over the steel. The use of rods was objected to by Behnke. It was generally agreed that large rods should be avoided and that small rods should be well covered with mesh and that all changes in steel quantities should be phased over a large area to avoid stress concentration. Agreement on the need for proper curing was registered, using either steam or water. Tamura suggested a combination of a very high temperature and pressure to assist in producing a new form of extra-strong concrete. The cost of ferro-cement boats was unfortunately not well discussed but it was generally considered to be favourable, although the advantage was reduced by restricting the ferro-cement content in the total structure to the bare hull. It was agreed that in some countries ferro-cement boats could be built indigenously, while boats of other materials would have to be imported at a much higher cost and involving expenditure of foreign exchange.

Session IV - Service Experience

(Thursday, 12 October 1972)

Mr. B.T. Cunningham (New Zealand) in the chair
Prof. M.A. Mowbray (New Zealand) acted as rapporteur

Session Papers

IV/1 "Survey of ferro-cement fishing craft built in New Zealand" by D.J. Eyres

IV/2 "Experience in regard to 300 commercially-built craft exported to over 20 countries" by T.M. Hagenbach

IV/3 "Ferro-cement boats - Service experience in New Zealand" by W.M. Sutherland

Papers also relevant: III/1, III/2, III/8

Rapporteur's introduction of session papers

Three papers were presented for discussion which, along with others in previous sessions, form an extremely valuable contribution to the mixture of art and science which forms ferro-cement construction. They certainly assist by pinpointing many of the important details in ferro-cement design and fabrication.

The paper by Eyres reports the view of a certifying authority and asserts the problems facing the naval architect and surveyor of ships when dealing with a material so unlike timber and metal and so dependent on faithful workmanship and the need for care at each and every step in the fabrication process. The appendix on the official requirements for boats built in New Zealand under survey is an excellent basic document as a code of practice without rigid rules. This indicates in which direction regulation of ferro-cement construction would be carried out for a while or even for always. Until such time as a more rational system of design is evolved, these regulations, together with the requirement of the production of drawings and calculations, seem reasonable and not likely to frustrate development unduly.

The contribution from Hagenbach is mainly devoted to a preliminary survey of customer reaction. It shows that while ferro-cement is not a universal choice it has a considerable degree of popularity amongst private owners and charterers of pleasure craft. Perhaps this contribution might have been more useful if the results of the survey for commercial boats had been separated and expanded. The author's record of damage and repairs is very worth while as it indicates the essential robustness of ferro-cement which is in contradiction to the belief popularly held by the layman that this material is extremely tender and brittle. The submission from Sutherland is based on personal experience as a designer and as a constructor with the result that it contains reference to many of those tricky points which have to be considered so carefully. The account of the misfortunes of his own boat the MAIRE after it had passed into other hands and had been stranded on a coral reef in Fiji are a tribute to Sutherland's personal skill as a ferro-cement boatbuilder. As a tail piece in that account a question is asked, namely "HOW STRONG IS STRONG ENOUGH?". This is indeed the essence of the purpose of this seminar.

Rapporteur's summary of discussions

The discussion ranged widely, relating in the main to details in ferro-cement boats with little comment being made on the gross problem of the suitability of the material as a shipbuilding medium.

The principal facts discussed were the correctness of using chicken wire as reinforcing mesh, the grouting and repair of voids when these are indicated by blisters in the paintwork, the penetration of ferro-cement by diesel oil and appropriate methods of lining fuel and water tanks, the insulation and protection of fish tanks and the problems of fastening fittings to ferro-cement hulls.

One fact that became clear was the ease with which both temporary and permanent repairs can be performed at the site of an accident and at a shipyard, even if the damaged section has to be treated under water.

It was also clear that many participants felt that the time was near when ferro-cement would be designed by calculation, using the usual design processes of load analysis, determination of induced stresses and design of suitable resistance from known material properties.

During this session a series of slides were presented by the participants from Cuba and showed that this country is well advanced in the construction of fishing vessels and ferries. This presentation was accepted by the assembled group with acclamation and formed a highlight of the proceedings.

To sum up, it can be safely said that ferro-cement, having been proved a safe and durable marine material for use in amateur pleasure craft, has now been developed to a stage where it must be considered seriously as an economic alternative to the traditional media, namely timber and steel and the more recently developed glass-reinforced plastic. The time has come to rationalize the design processes, using knowledge already available to structural engineers and marine architects. There is no doubt that ferro-cement will remain a material appropriate to communities with relatively low wage rates because it is a labour-intensive

process. However, even in countries with high labour costs as exist, say, in New Zealand, developments of new fabrication techniques could easily make this material economically competitive in the more developed countries.

Finally, ferro-cement must not be thought of as a cheap substitute for timber and steel but as a worthy competitor which has admirable and unique properties in its own right. Taking all in all, ferro-cement can and should be a constructor's first choice in many cases if he is prepared to forego his prejudices and be prepared to make a reasoned judgement of his problem.

In spite of the importance of the subjects covered in the three previous sessions of this Seminar, perhaps this, the fourth and last session of discussion and of exchange of information, was the most important in that the in-service performance of existing ferro-cement crafts has been examined and proved on the whole to be excellent.

There is an old English adage which runs "the proof of the pudding is in the eating thereof" and, although in this case the pudding has been somewhat small, there has been more than enough to show that the recipe is good, the cooking excellent and the final dish acceptable though not to every man's taste.

In Session IV there has been presented some information on which to judge the serviceability of ferro-cement craft, not in great detail but sufficient to justify continuing faith in both the material and the techniques of construction when these are properly applied.

One aspect is clear, namely that there seems to be no evidence of gross failure under normal service conditions nor unexplained losses at sea. Such comment as has come forward related more to detail rather than to the constructional system as a whole.

TOUR OF AUCKLAND BOATYARDS (Friday, 13 October 1972)

The majority of the participants went on the tour organized by the host Government and flew to Auckland on the evening of Thursday, 12 October.

The tour started at 08.30 hours on Friday, 13 October, and participants were able to see both amateur and professional combinations of ferro-cement vessels in the Auckland area. The tour provided an opportunity to pursue discussions started during the formal sessions in Wellington and to observe at first hand a variety of construction techniques followed by various builders. The extensive use of ferro-cement as a boatbuilding material by amateur builders was particularly noteworthy, as was the general high standard of their work.

Highlights of the tour were:

(i) Visit to Span Farm at Henderson: The farm is a most interesting example of a cooperative enterprise of a group of amateur builders and professional boat designers. Several small boatbuilding enterprises are located within its precincts and guidance is provided by designers to the amateur builders devoting all their spare time to construction of their own boats.

(ii) Visit to Ferro-Cement (New Zealand) Ltd. at Greenhithe: Participants had the opportunity to see hulls at various stages of completion and, in particular, to observe the application of the new sandwich technique employing integral wooden battens, a newly developed mesh type, two-shot plastering method. A demonstration of the fire resistance of ferro-cement was given.

(iii) Visit to Ferrocraft Marine Ltd. at Takapuna: The fitting out of ferro-cement craft was seen and participants had the opportunity to continue their discussions over a luncheon provided by the firm.

(iv) Visit to one of the Auckland yacht marinas where a good number of old and new ferro-cement yachts could be seen.

Appendix I

Address by the Hon. D.J. Carter

(Opening address delivered by the Hon. D.J. Carter, Minister of Agriculture and Fisheries, in the absence of the Hon J.B. Gordon, Minister of Transport.)

I am pleased indeed to have the honour of opening your seminar and especially to have the opportunity of meeting all those visitors from other countries who are taking part.

We in New Zealand enjoy meeting visitors, especially those visitors who have technical expertise, because we can learn from them.

This seminar gives us a chance of meeting people who have a positive aim of helping other people. Some may have problems which I hope the seminar will go a long way towards solving. You are concerned with something which I know will ultimately benefit a great many people.

New Zealand provides an excellent venue for this seminar because it has been a world leader in the ferro-cement boat field. New Zealanders have a great "do-it-yourself" spirit which has inspired many amateurs to make their own ferro-cement craft. I've even come close to putting golf balls into two such craft next to the 18th at Miramar Golf Club. I do not exaggerate when I say there are hundreds of these vessels around our shores, used as pleasure craft by weekend boating enthusiasts. Quite a number of these craft have been built for commercial use, some of them for fisheries.

A lot of the men who have built and used these vessels for commercial fishing have been pioneers in this field. Their initiative and enterprise have paved the way for the development of such craft. Official recognition arrived when some of them came under the jurisdiction of the Ministry's marine division and, as a consequence, studies were initiated in this field of construction.

The techniques used by some of the early boatbuilders and the ensuing practical results laid the foundation for the work of this seminar, the results of which will, I trust, be disseminated in various parts of the world.

We do not claim credit for inventing this method of boatbuilding in New Zealand. Its recent development dates back to the 1940's with Prof. Nervi's experiments. As you know, the process is much older, in fact almost as old as New Zealand itself. I understand the first experiments were carried out in France in 1840, the year New Zealand came officially under the protection of the British Crown. It is interesting to think that the French were trying out this type of vessel while the Maoris of New Zealand were sailing their ornately carved canoes and their rafts hewed from trees from our native forests.

One important reason for holding this seminar is because of the potential for using ferro-cement to build fishing vessels in countries developing the industry as an important source of food. This was recognized in the 1960's by the United Nations Food and Agriculture Organization which has already provided technical aid to many countries to build these boats for fishing.

The ferro-cement vessel, whether used for fishing or for transport - particularly on inland waterways - offers some significant advantages over other more conventional hulls. For example, their manufacture does not call for expensive shore installations for construction. Their building does not demand an army of experts highly skilled in a variety of trades. The skills called for in building them can often be found readily in many less-developed countries. Such skills can be quickly taught and readily assimilated. The materials for construction are generally widely available and in many cases are indigenous. The ferro-cement hull, if not too badly damaged, is easily and simply repaired. I believe that the ferro-cement vessel is capable of ready adaptation and use in many countries for fishing and transport.

It is a source of great satisfaction for us in New Zealand to be the host country for such a seminar. Of course, we haven't brought you here to lecture to you and show off our expertise. We expect to gain a lot by the exchange of ideas and the knowledge each one of you has brought of boatbuilding and the fishing industry in your own countries. We hope you might find the answers to some of the problems that you have encountered at home and we, in turn, will look for ideas and solutions to ours.

You are all most welcome here and I hope you will have the opportunity of seeing something of New Zealand while on this visit, as well as gaining the knowledge you require for your own purposes. I hope, too, that your visit here may tempt you to return.

I am pleased to declare this seminar open and I wish it great success and worth-while results.

Appendix II

Address by Mr. P. Gurtner

(FAO Secretary)

It is a great honour for me to address this gathering during the opening ceremony of the first FAO fisheries meeting to be held in New Zealand. I bring to you all the greetings of the Director-General of FAO and the FAO Department of Fisheries with best wishes for the success of the Seminar on the Design and Construction of Ferro-Cement Fishing Vessels.

The topic we have chosen for this seminar is a very specialised one. I note with great satisfaction the response you have all made to the invitation we issed on behalf of the Government of New Zealand to gather here in Wellington for a week of technical discussions and exchange of information.

I personally consider this topic to be of outstanding importance in the world-wide attempts at upgrading and developing a most important sector of the fishing community, one which up to now has only received sporadic and often unsatisfactory assistance. You realise, I am sure, that I speak of what we call, in FAO terminology, artisanal and subsistence-level fisheries. We are firmly committed in FAO to increasing our involvement in all actions aiming at providing solutions to the seemingly insurmountable problems which have prevented develop- in this area from keeping pace with that in the more industrialised fisheries. My colleagues here and those in Rome share my conviction that one of the key problems requiring solution is that of providing the artisanal fishermen with improved boats and gear without unduly increasing capital investment in this equipment. We believe that this is an essential condition to assure that the increased income to be expected from the use of better boats and gear is indeed available to the artisanal fishermen to raise their generally low standards of living. We must constantly look out for new materials and techniques to build improved boats cheaper or at least at comparable cost to the existing indigenous craft and I am sure that ferro-cement will play an increasingly important role in this development.

In FAO we are relative latecomers to the fraternity of believers in the use of ferro-cement for fishing boat construction. Our interest in this material was only stirred in the late sixties, when we observed the growing use of this building technique, particularly here in New Zealand, and when our attention was drawn to the fact that we had the good fortune of being located in Rome in close proximity to Professor Pier Luigi Nervi. We hastened to establish close personal relations with Professor Nervi who was more than ready to assist us in our efforts to learn more about the new material he had so successfully developed many years earlier.

I regret that Professor Nervi is not able to attend this meeting. As something like the spiritual father of the ferro-cement technique, he would have been a most valuable contributor to our forthcoming deliberations and it would have been a matter of great personal satisfaction for him to observe the measure of importance which his invention has assumed in the field of boatbuilding.

During our early attempts to utilize the new technique we soon realised that the material and its application were not quite as simple and straightforward as many wanted us to believe. We felt the need to base our development work on sound engineering practice, to avoid the possibility of failures that would set our attempts back by years. Thus the idea was born of convening an international conference on the subject of ferro-cement and its application in the field of boatbuilding. From the beginning, this conference was conceived as a gathering of experts, aiming at making available to a wider public the existing basic engineering data, knowledge of different application techniques and service experience and to clarify the numerous claims of a technical or economic nature that many had made for the new material.

New Zealand has long been a centre of development work with ferro-cement and it was only natural that we should have wished to convene this meeting in this beautiful country. We are deeply grateful to the Government of New Zealand for agreeing to host this meeting and we appreciate very much, Honourable Minister, that you have personally welcomed the participants and that you have, indeed, allowed this FAO Seminar to interfere with your heavy commitments.

We are most conscious of the importance your Government attaches to this meeting and we sincerely appreciate the honour of being allowed to convene in these chambers for our opening ceremony. We are most encouraged by the enthusiastic support we have received from your Government throughout the period of preparation of the Seminar and I trust that, with continuing official support and the collaboration of all participants, we shall be able to achieve the results we have envisaged.

Appendix III

Address by Mr. B.T. Cunningham

(Director of Fisheries, Ministry of Agriculture and Fisheries, Government of New Zealand, and Chairman, Indo-Pacific Fisheries Council)

As Chairman of the Indo-Pacific Fisheries Council which is concerned with the development and management of fisheries resources within the Indo-Pacific region, I am pleased that this Seminar on the design and construction of fishing vessels is being held in New Zealand. I say that because I am a New Zealander, as you know, and while I am still speaking in that capacity may I express the hope that the representatives of all the countries enjoy their short stay here.

For some time the Indo-Pacific Fisheries Council has realised the need to improve the quality of fishing vessels, particularly for the developing island communities within the Council's domain, having regard for the cost of building and maintaining traditional wooden or steel vessels. Because of this we have been attempting to have this type of seminar held for specialists from throughout the Indo-Pacific region, supplemented by other experts from throughout the world, so that they could get together and fully discuss the problems associated with the increasing use of this type of craft.

As far as the Council is concerned, the emphasis is naturally on fishing vessels. At the same time, however, the Council is appreciative of the fact that ferro-cement vessels of all types could have many uses and advantages throughout the area but perhaps more particularly in the tropical regions.

I think it is accepted that instruction in the skills of operating ferro-cement fishing vessels throughout the Indo-Pacific region is important and necessary, as yards specialising in this type of construction are already established in Hong Kong, Western Samoa, New Caledonia, Fiji, Tahiti, Australia, the American Trust Territories, the Philippines, India and, of course, New Zealand.

As Chairman, may I say that I am pleased that the New Zealand Government has been able to give its support to the Indo-Pacific Fisheries Council and FAO in the organization of this technical seminar and also that it has been possible for these discussions to be associated with the Fifteenth Session of the Indo-Pacific Fisheries Council scheduled to begin on 18 October.

I trust that the detailed discussions over these four days, and the inspection of ferro-cement boats under construction at Auckland, will assist in expanding and modernising the fishing fleets throughout the Indo-Pacific region.

On behalf of the Council I would be pleased if you, Mr. Carter, would convey to the New Zealand Government our thanks for hosting this Seminar.

Appendix IV

List of Participants

Australia

Amundsen, Trygve
Principal Surveyr Dnv
Norske Veritas
A.D.C. House, 8th Floor
77 Pacific Highway
North Sydney, 2060 N.S.W.

Blackney, R.J.
Fisheries Extension Officer
Northern Territory Administration
Fisheries Section
Darwin, N.T. 5790

Boden, C.E.
Director and Naval Architect
Cecil E. Boden and Associates
695-697 George Street
Sydney, N.S.W. 2000

Buchner, T.E.
Senior Lecturer
School of Civil Engineering
The New South Wales Institute of Technology
Thomas Street
Broadway, N.S.W. 2007

Bull, D.J.
Company Representative
J.C. Bull & Staff
Metung
Gippsland Lakes
Victoria 3904

Ellen, Peter E.
Managing Director
Elstress Pty. Ltd.
25 Kings Road
Hornsby, N.S.W. 2077

Gladigau, B.J.
Sales Manager
Queen's Bridge Motors Pty. Ltd.
12 Turnbull Avenue
North Clayton
Victoria

Holland, V.W. (Dr.)
11 Dorset Road
Northbridge
Sydney, N.S.W.

Janes, C.D. (Captain)
Assistant Naval Architect
Ship Structures Safety Branch
Marine Standards Division
Department of Shipping & Transport, 7th floor
35 Elizabeth Street
Melbourne
Victoria 3000

Mounsey, P.
Director
Ferro-Cement (N.Z.) Ltd.
5/28 Waruda Street
Kirribilli, N.S.W.

O'Kell, E.W.
Manager
O'Kell's Boat Plans
P.O. Box 1228
Townsville
Queensland 4810

Perry, E.J.
Consulting Engineer
23 Birdwood Street
Sylvania Heights
N.S.W. 2224

Rossiter, M.W.
Director
Techmarine
Box 336
Salisbury 5108
South Australia

Tait, A.R.L.
Chief Representative for Bureau Veritas
in Australia
69 Macquarie Street
Sydney, N.S.W. 2000

Walker, K.
Walker Boat Co.
Wattlepark Avenue
Moolay
Geelong
Victoria 3219

Australia (continued)

Watkins, A.J.
Senior Engineer Surveyor
Marine Board of Queensland
Department of Harbours and Marine
Box 2195
Brisbane 4001

Worsnop, F.E.
General Manager (Marketing)
c/o Dimet Corrosion Pty. Ltd.
P.O. Box 166
South Melbourne
Victoria 3205

Bangladesh

Ali, M. Youssouf (Dr.)
Director of Fisheries
Government of People's Republic of Bangladesh
81 Kakrail Road
Dacca 2

Brazil

Miguel, D.C.
Naval Engineer
Av. Paulino Muller, 1148
Vitoria - E.S.

Canada

Bigg, Gordon W. (Prof.)
Associate Professor
Carleton University
1105 Normandy Cres.
Ottawa K2E 5A3
Ontario

Norris, C.F.
Design Director
Samson Marine Design Ltd.
833 River Road
Richmond
Vancouver B.C.

Cuba

Gaitan, J.A.
Naval Engineer
21 Street Vedado
Habana

Lobek, E.M.
Civil Engineer
University of Havana and I.N.P.
Central 14114, Martin Perez
Guanabacua

Sanchez, G.C.
Chief, Production
Shipyard Enterprise
Oficios 452
Habana

Seoane, A.M.
Manager, I.N.P.
Oficios 452
Habana

Fiji

Spottiswoode, J.M.
Acting Principal Fisheries Officer
Department of Agriculture
Fisheries Division
Suva

India

Kanakasabapathy, Thiru
Works Manager
Fisheries Boatbuilding Yard
143A Poonamallee High Road
Aminjikarai
Madras 29

Indonesia

Eadie, D.H.
Manager
West Irian Joint Development Foundation
UNDP/FUNDWI 23
Box 2338
Djakarta

Japan

Tamura, K.
Japan Ferro-Cement Boat Ltd.
4-14-3 Kajinocho Koganeishi
Tokyo

New Guinea

Wells, D.J.
Manager
Madang Ferroconcrete Industries
P.O. Box 491
Madang

New Zealand

Anderson, J.
Chief Engineer Survey and Surveyor of Ships
Marine Division
Ministry of Transport
Private Bag
Wellington

Betteridge, P.
Principal Surveyor for New Zealand
Lloyd's Register of Shipping
G.P.O. Box 2129
Wellington, C.1

Bickford, R.N.
Boat Builder
50 Castor Bay Road
Castor Bay
Auckland

Bowen, G.L. (Dr.)
Civil Engineering Department
The University of Auckland
Private Bag
Auckland

Breekveldt, G.
Marine Architect
P.O. Box 2642
Auckland

Carkeek, G.
Managing Director
Ferrocraft Marine (NZ) Ltd.
P.O. Box 31042
Milford
Auckland

Carr, Athol James
Senior Lecturer
Department of Civil Engineering
University of Canterbury
Private Bag
Christchurch 1

Collins, E.H.C.
Boatbuilder
P.O. Box 354
Blenheim

Davidson, L.K.
Marine Architect
57 Karaka Street
Takapuna
Auckland 9

Donovan, B.W.
Marine Architect
1 Takarunga Road
Devonport
Auckland 9

Eyres, D.J.
Principal Surveyor of Ships
Naval Architect
Marine Division
Ministry of Transport
Private Bag
Wellington

Farrell, N.K.
American Bureau of Shipping
P.O. Box 14-038
Panmure
Auckland 6

Fountain, A.D.
Secretary/Manager
Nelson Technical Institute
P.O. Box 64
Nelson

Greig, R.
Corrosion Engineer
Dimet Corrosion Limited
P.O. Box 9137
Wellington

Hall, R.
Technical Adviser
Waikato Ferro-Cement Marine Assn.
7 Awatere Avenue
Hamilton

Hewetson, S.D.
New Zealand Agent
Samson Marine Designs Ltd.
Box 4254
Auckland

Hunt, P.B.
Technical Consultant
Consolidated Chemicals
Box 15104
New Lynn
Auckland

Jardine, R.
Tutor in Boatbuilding
New Zealand Technical Correspondence Inst.
53 Riddlers Crescent
Petone
Wellington

New Zealand (continued)

Kerr, R.N.
Director
Marine Division
Ministry of Transport
Private Bag
Wellington

Kidson, C.B.
Manager
Kidson Construction Limited
8 Whitby Road
Nelson

McDonald, M.J.
Manager
Dricon Industries Ltd.
Box 91
Tuakau
Auckland

Moar, H.M. (Dr.)
Technical Director
Ferro-Cement New Zealand Ltd.
31 Miramar Place
Pakuranga
Auckland

Mowbray, M.A. (Prof.)
Professor of Civil Engineering
The University of Auckland
Private Bag
Auckland

Officer, K.C.
Director
Ferro-Cement (N.Z.) Ltd.
P.O. Box 1376
Auckland

O'Loughlin, John
Senior Engineer
4 Farndale Place
Christchurch 4

Parsons, N.F.
Technical Officer
Fishing Methods
Fishing Industry Board
P.O. Box 9232
Wellington

Reid, D.H.
Managing Director
Ferro-Cement (N.Z.) Ltd.
P.O. Box 1376
Auckland

Richardson, W.E.
Development Supervisor
128 Somerville Street
Anderson's Bay
Dunedin

Robb, D.F.
Company Director
D.F. Robb & Co. Ltd.
P.O. Box 127
Timaru

Roberts, R.J.
Chairman, Technical Committee
Waikato Ferro-Cement Marine Association
365 Cobham Drive
Hamilton

Robinson, W.V.
Director
Ferro-Cement (N.Z.) Ltd.
P.O. Box 1376
Auckland

Ross, C.
Manager
Kidson Construction
120 Songer Street
Stoke
Nelson

Russell, W.J.
Director
Ferro-Cement (N.Z.) Ltd.
P.O. Box 1376
Auckland

Scrivener, J.C.
Reader in Civil Engineering
Department of Civil Engineering
University of Canterbury
Private Bag
Christchurch

Sparrow, P.C.M. (Dr.)
c/o 192 Kohimarama Road
Kohimarama
Auckland 5

Vialle, T.H.
Solid Plastering Contractor
40 Harbour Drive
Tauranga

New Zealand (continued)

Waters, W.
Naval Architect
Union Steamship Co. N.Z. Ltd.
12 Streatham Crescent
Strathmore
Wellington 3

Wheeler, G.
Manager
Ferrocraft Marine
44 Birkdale Road
Auckland

Wood, R.A.
Sales Manager
Wellington Regional Manager
Expandite Limited
P.O. Box 27146
Wellington

Wylde, F.G.
Boatyard Manager
18 Marie Avenue
Te Atatu
Auckland

Norway

Hermanson, H.E.
Company Director
Box 60
Farsund 4551

Sri Lanka

Ballingall, J.M.
Chief Engineer
Harrisons Lister Engineering Ltd.
P.O. Box 69
Colombo

Thailand

Nontanakorn, Dusit
Engineer-in-Charge of Ferro-Cement Project
The Construction Material Marketing Co. Ltd.
P.O. Box 1770
Bangkok

Pama, R.P. (Dr.)
Assistant Professor
Asian Institute of Technology
P.O. Box 2754
Bangkok

Phromratanopongse, Opas
Head of Construction Department
Siam Cement Company Ltd.
P.O. Box 572
Bangkok

United Kingdom

Hagenbach, K.M.
Sales Director
The Manor House
Wroxham
Norwich
Norfolk

United States of America

Behnke, Robert B.
President
The Systems Corporation
1441 Kapiolani Boulevard
Honolulu
Hawaii 96814

Doleman, E.C. (Ltg. USA Ret.)
Consultant and Director
The Systems Corporation
1341 Pueo Street
Honolulu
Hawaii 96814

Romualdi, J. (Prof.)
c/o Carnegy
Mellon University
Pittsburgh
Pennsylvania

Vietmeyer, Noel D.
Professional Associate
National Academy of Sciences
2101 Constitution Avenue
Washington D.C. 20418

United Nations Industrial Development Organization (UNIDO)

Sannergren, A.
Shipyard Manager (OPAS)
UNIDO
Marine Department Shipyard
Walu Bay
Suva
Fiji

Appendix V

List of Seminar Officers

Host Government

Chairman	Cunningham, B.T. Director of Fisheries Fisheries Division Ministry of Agriculture and Fisheries P.O. Box 10142 Wellington
Technical Adviser to Chairman	Anderson, J. Chief Engineer Surveyor and Surveyor of Ships Marine Division Ministry of Transport Private Bag Wellington
Conference Liaison Officer	England, N.E. (Miss) Ministry of Foreign Affairs Private Bag Wellington
Conference Liaison Officer	Watkinson, J.G. Ministry of Agriculture and Fisheries P.O. Box 10142 Wellington

FAO

Technical Secretary	Gurtner, Peter Chief, Fishing Vessels and Engineering Branch Department of Fisheries Food and Agriculture Organization Via delle Terme di Caracalla Rome, Italy
Associate Secretary	Gulbrandsen, Øyvind Naval Architect Fishing Vessels Section Department of Fisheries Food and Agriculture Organization Via delle Terme di Caracalla Rome, Italy
Associate Secretary	Fyson, J.F. Fishing Boat Development Adviser Department of Fisheries Food and Agriculture Organization Via delle Terme di Caracalla Rome, Italy
Conference Officer	Jiannee, A. (Miss) Technical Assistant (Fisheries) FAO Regional Office for Asia and the Far East Maliwan Mansion, Phra Atit Road Bangkok 2, Thailand

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